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CAMOUFLAGE BY ARTIFICIAL FOLIAGE

N. C. Henderson, et al

Battelle Columbus Laboratories

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Army Land Warfare Laboratory

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A program was conducted to develop a pop-up artificial-foliage system compatible with the rural Maryland (summertime) background environment. The result of this Phase I effort was a self-expanding leaf module, a number of which are stored flat in a simple box-like container. Release of the container lid latch allows the leaf modules to pop-up and expand, thus covering the external surface of the vehicle with artificial foliage. Repacking is accomplished by pulling a lanyard threaded through each leaf

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module. Visual background experiments with the leaf modules deployed verified the overall effectiveness of this camouflage system against visual detection.

FOREWORD

This report summarizes research conducted under Contract Number DAAD05-73-C-0526 from June 6, 1973, through June 6, 1974. The research was performed by the Columbus Laboratories of Battelle Memorial Institute under the auspices of the U. S. Army Land Warfare Laboratory, Aberdeen Proving Ground, Aberdeen, Maryland, with Mr. Joe Swisher and Mr. Larry Baer serving as project monitors. The principle investigators were R. J. Dick, P. M. Grandinetti, N. C. Henderson, G. R. Riley, and D. E. Roop.

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FINAL REPORT

on

CAMOUFLAGE BY ARTIFICIAL FOLIAGE

by

N. C. Henderson

to

U. S. Army Land Warfare Laboratory
Aberdeen Proving Ground, Maryland

INTRODUCTION

Camouflage techniques currently used for vehicles and aircraft (on the ground), generally involve either reliance on the original color of the vehicle (e.g., olive-drab paint), or the placement of camouflage netting over the equipment augmented with natural foliage. The latter camouflage technique can be very effective; however, considerable time is involved in effecting the procedure. In addition, the foliage must be replaced periodically since noticeable color changes occur with the "dead" foliage within a relatively short period of time. One partial solution is the use of artificial foliage which can be rapidly attached to a combat vehicle in the field, thus reducing the amount of time required in renewing natural foliage camouflage.

Some time ago, the U.S. Army Land Warfare Laboratory, Aberdeen Proving Ground, Maryland, requested that Battelle briefly investigate the use of "instant foliage" which would be artificial foliage, vehicular mounted, automatically and rapidly deployed, and designed to provide maximum deployed foliage volume with minimum storage requirements. The results of this study were included in a TACTEC report entitled "Concept Generation for Instant Foliage" (Report No. LWL-61Q), November, 1972.

Two major concepts based largely on professional magician's "tricks" resulted from this effort. The first concept used the principle of a "magic bouquet" and consisted of a number of spring-loaded "flowers" which were

constructed from thin paper and vinyl which folded into a compact volume. Thin steel springs glued to each flower provided the forces to automatically expand the paper.

The second idea was the adaptation of the "appearing cane", another magic trick. The cane is constructed of thin spring steel which in the "relaxed" state forms a spiral tube which looks (from a distance), like a white-tipped walking cane. When the cane is compressed axially, the volume is significantly reduced and the cane can be easily hidden in the hand. Release of the compressed tube allows the cane to spring rapidly into the extended position.

The "magic bouquet" is shown compressed in Figure 1, and in the expanded position in Figure 2. A detail of one "flower" is shown in Figure 3. The compressed bouquet can be contained in a volume of 3/8 x 3 x 3 inches and expands into a volume approximating a sphere 8 inches in diameter. This is an expanded volume-to-stored volume ratio of about 80:1.

A photograph of the "appearing cane" is shown in Figure 4. Its major advantages are its self-erec ng capability, speed, and general simplicity.

It was concluded tha nstant" artificial foliage, based on the principles of the magician's "magic bouquet" and "appearing cane", could be effectively utilized to produce instant artificial foliage for use as a potential camouflage technique. Although much of the effectiveness of the foliage would depend on its color match with the background, the mechanics of the concept appeared relatively simple and a large volume of camouflage could be produced from a relatively small storage volume.

On February 2, 1973, a Request for Quotation (RFQ) was received from the Aberdeen Proving Ground describing a need for a "pop-up" artificial camouflage system. A research program utilizing the above principles was submitted in response to that RFQ and was subsequently accepted. The following report describes the Phase I research effort conducted to develop a pop-up artificial foliage camouflage system from June 6 through December 15, 1973.

FIGURE 1. MAGICIAN'S "MAGIC" BOUQUET SHOWN COMPRESSED

FIGURE 2. MAGICIAN'S "MAGIC" BOUQUET SHOWN EXPANDED

FIGURE 3. DETAIL OF ONE "FLOWER" FROM "MAGIC" BOUQUET ILLUSTRATING FOLDING METHOD USED

FIGURE 4. MAGICIAN'S "APPEARING CANE"

FIGURE 3. DETAIL OF ONE "FLOWER" FROM "MAGIC" BOUQUET ILLUSTRATING FOLDING METHOD USED

FIGURE 4. MAGICIAN'S "APPEARING CANE"

EXECUTIVE SUMMARY

The purpose of this research program is to develop a reuseable artificial foliage-type camouflage system which is to be compatible with the natural foliage of rural (summertime) Maryland. This system is to be stored in a compact configuration on a vehicle when not in use and have the capability to be rapidly deployed, i.e., "pop-up" within 15 seconds, with the capability of being repacked in approximately 15 minutes.

As a result of this research, a spring-leaf system was developed. This system consists of a number of spring leaf modules which are stored in box-like containers when not in use. Each spring leaf will expand to many times its storage volume of its own accord. The system is self-energizing, i.e., the stored spring energy of each leaf module is sufficient to deploy the complete system (jack-in-the-box fashion) and no additional energy sources are required.

In use, a number of containers are placed on the exterior surfaces of the vehicle. Each container holds five to ten modules. Release of the container lid by a simple latch allows the leaf modules to "pop-up" and expand. As a result, the exterior surfaces of the vehicle are covered with realistic appearing artificial foliage as shown in Figure 8.

Repacking is accomplished by pulling a lanyard threaded through all of the leaf modules associated with a given container. The leaf modules automatically compress into a flat configuration whereby they can be easily re-inserted into the storage container.

Visual background experiments, conducted at Battelle's West Jefferson outdoor test facility, verified the overall camouflage effectiveness. The vehicle silhouette was effectively disrupted and the blending of the foliage with the four different backgrounds tested was proven visually effective.

Two complete camouflage systems, suitable for use with a M151-A2 jeep, were fabricated and shipped to the Mobility Equipment Research and Development Center (MERDC) at Ft. Belvoir, Virginia, for further evaluation.

CONCLUSIONS

Based on the research effort conducted during this program, it was concluded that a rapidly deployed pop-up artificial foliage system can be developed which will yield a large amount of silhouette disrupter per unit of storage volume and which can be repacked in a reasonable period of time. It was further concluded that the artificial foliage can be designed to blend effectively with a variety of natural backgrounds as long as some indigenous foliage is in evidence.

RECOMMENDATIONS

It is recommended that the two prototype artificial camouflage systems fabricated during this research program be extensively tested at MERDC and that the results of these tests be used to further refine and develop the pop-up foliage concept.

It is further recommended that the artificial pop-up foliage concept be integrated into the vehicle structure on a prototype basis and evaluated as an inherent part of the vehicles overall defensive posture.

RESEARCH ACTIVITY

The overall objective of this research program is to develop an artificial foliage-type of camouflage system, compatible with a background environment typlified by the rural Maryland area in the summer time frame and which can be stored in a compact configuration on a vehicle, with the capability to be rapidly and automatically deployed, yielding a large amount of silhouette disrupter per unit of storage volume. Additional specific objectives and desired system characteristics defined for the camouflage system were as follows:

(1) Attached to the vehicle

(2) Will not interfere with vehicle operation in its stored mode

(3) Will be reusable following activation

(4) Easily attached to the vehicle (within 15 minutes)

(5) Capable of disrupting the silhouette of a 1/4-ton military vehicle at a range of 500 meters or less

(6) Capable of being deployed in 15 seconds or less

(7) Capable of being repackaged in 15 minutes or less.

The research effort conducted to meet these objectives is described in detail below. The specific foliage design resulting from this effort is discussed first, followed by a description of other concepts considered during this program, materials investigation, spring designs, container designs, repacking concepts, and field experiments at West Jefferson, Ohio and Aberdeen Proving Ground.

Description of Pop-Up Artificial Foliage Concept

The artificial foliage concept generated during this program is based largely on the "magic bouquet" described in the Introduction of this report. The system contains only two major elements: a group of spring "leaf" modules and a container for storage. These elements are photographed in Figure 5 which also shows a lanyard attaching the leaf module to the

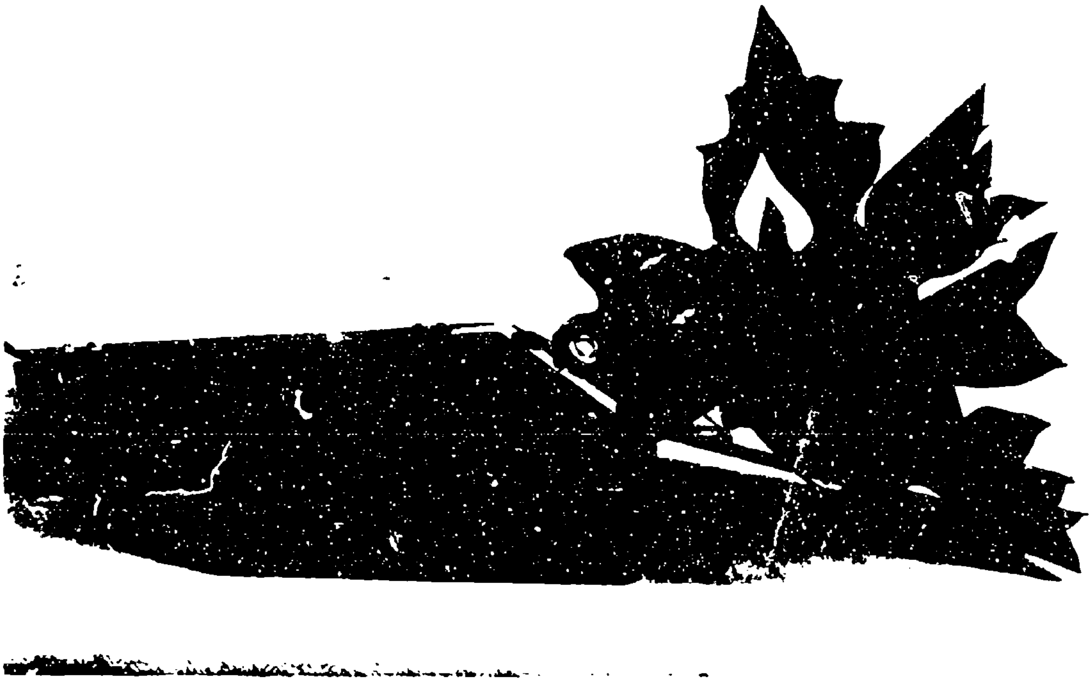

FIGURE 5. TWO MAJOR ELEMENTS OF ARTIFICIAL POP-UP FOLIAGE SYSTEM: (1) SPRING LEAF MODULE AND (2) CONTAINER

container. For clarity, only one leaf module is shown; however, the container pictured will hold 20 leaf modules. Figure 6 shows a leaf module disassembled into its two major components: its activating steel spring and the artificial leaf material. The module shown in Figure 6 uses 65 pound cover weight light-green paper on which is printed a leaf pattern. The actual prototype system discussed in the following section uses a synthetic or "plastic paper" which is considerably more durable overall and is essentially tearproof.

Figure 7 is a photograph of a "clump" of 20 leaf modules positioned next to a container which can hold all of the modules shown. In actual use the container would be beneath the clump and therefore would not be visible. Figure 8 shows a number of "clumps" mounted on a M38A1 jeep and illustrates the overall effectiveness of the pop-up leaf modules as a silhouette disrupter. A relatively good blend into the background can also be noted.

Activation of the pop-up foliage merely requires release of the container latch. The latch may be a simple mechanical device (in our case, a pin on a short lanyard) or an electrical solenoid latch may be used. The spring contained in each leaf module supplies all of the "pop-up" energy required and therefore no additional energy source is required unless an electric solenoid latch is anticipated.

Repacking is accomplished by pulling a long lanyard which automatically closes all of the modules. This lanyard is threaded through the leaf modules as shown in Figure 9 and the result of pulling on the lanyard is shown in Figure 10. The modules would then be replaced in the container, the lid latched, and the system would be ready for instant reactivation.

FIGURE 6. TWO COMPONENTS OF LEAF MODULE: (1) ARTIFICIAL LEAF MATERIAL AND (2) STEEL SPRING

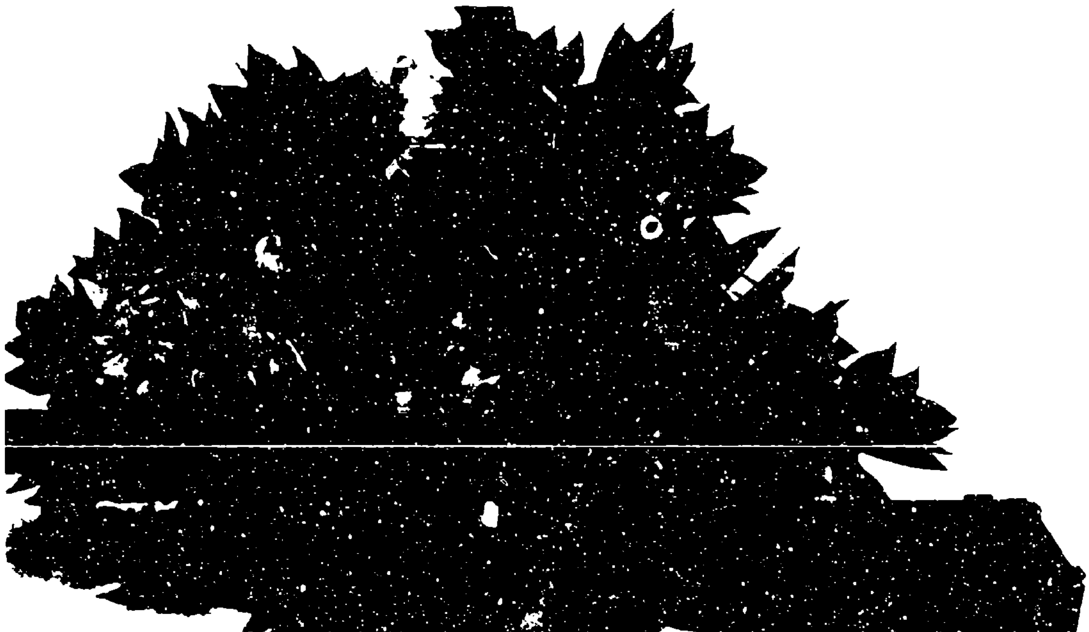

FIGURE 7. CLUMP OF TWENTY LEAF MODULES AND ITS CONTAINER

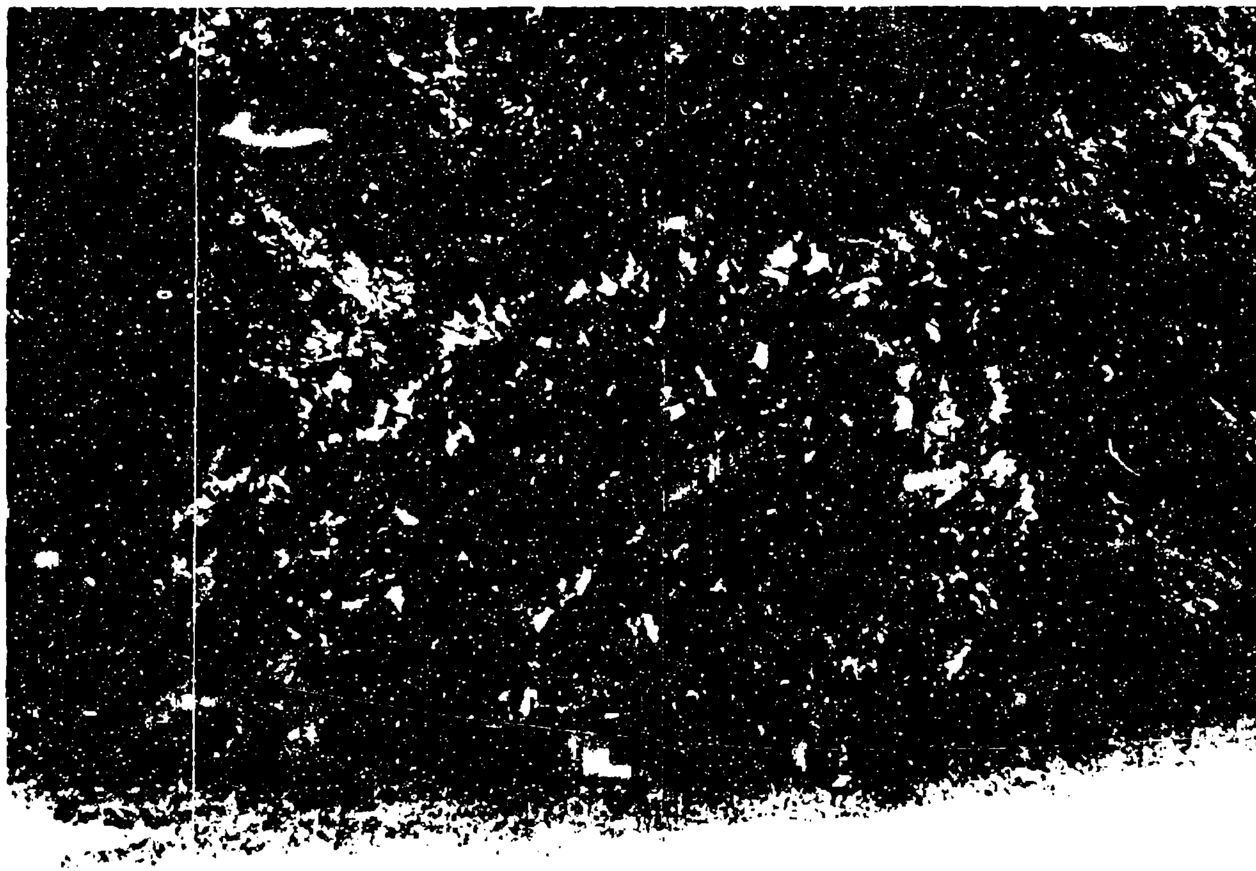

FIGURE 8. M38A1 JEEP WITH SPRING-LEAF CAMOUFLAGE IN PLACE
(PHOTOGRAPHED AT A DISTANCE OF 25 FEET) (35 MM FILM)

FIGURE 9. SPRING LEAF MODULES WITH REPACKING LANYARD

FIGURE 10. SPRING LEAF MODULES COMPRESSED AFTER PULLING ON LANYARD.

Description of Prototype Pop-Up Artificial Foliage System

Two sets of a prototype pop-up artificial foliage system, designed to be attached to a M151-A2 jeep, were fabricated during this program. The prototype system is identical in principle to the paper foliage discussed above; however, the prototype leaf modules are physically larger, more detailed, and considerably tougher than the paper modules. A sample of the leaf module material used is enclosed with this report.

The material used for the "leaves" is an artificial paper,* a high density polyethylene. To obtain the required module material stiffness, two sheets of high density polyethylene were laminated together using Epon 828, an epoxy resin, and an amine catalyst. The leaf material was printed with a leaf pattern using a full four-color printing process. The leaf modules were cut from the base stock and embossed using dies specifically made for this purpose.

The springs were fabricated from 0.030-inch thick spring steel and assembled to the leaf material using green binding tape and tinner's rivets. It should be noted that this assembly technique, although considered adequate for the two prototype systems, is inadequate for any production size quantity of leaf modules. In quantity, the springs would be bonded to the leaf material using an adhesive and/or heat sealing, possibly augmented with a rivet or staple-type of fastener. In addition, radar scattering filaments should be incorporated into the adhesive used to laminate the leaf material, and UV compatible pigments should be used for printing.

The two prototype systems delivered during this program consisted of 150 leaf modules, grouped together in "bundles" of 5 modules per bundle for a total of 30 bundles. Thirty containers, fabricated from steel and aluminum, were also supplied, i.e., one container per bundle. It was originally proposed to attach the containers directly to the metallic surfaces of the jeep using a double sided adhesive tape. However, removal of the containers from the vehicle was found to be difficult, and a high

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* Acro-Art, manufactured by the Mead Paper Company.

potential existed for damaging the painted surfaces of vehicles * while removing the containers. To eliminate these problems, a system of nylon straps, clip, and buckles was devised, which can be easily attached to and removed from the vehicle. The leaf module bundles are snapped onto D-rings positioned at appropriate places along the straps. Specific details describing how to attach, erect, repack, and remove the camouflage system (in conjunction with a standard M151-A2 jeep) are outlined in a "Field Manual For Use of Pop-Up Artificial Foliage With a M151-A2 Jeep".

Figure 11 shows the camouflage leaf bundles in the packed mode on a standard M151-A2 vehicle. Figure 12 shows the camouflage in the erected mode. The camouflaged vehicle is shown in Figure 13 , photographed at a distance of approximately 50 meters, and without camouflage at the same distance in Figure 14 .

As can be noted in the photograph, the leaf modules provide excellent silouette disruption of the relatively "square" body design of the jeep. The color match of leaf modules was found unacceptable at close distances (less than 20 meters). However, at distances greater than 100 meters, the color mismatch was much less noticeable. The color problems noted with the prototype system can be relatively easily corrected in future systems.

The embossed leaf pattern was also somewhat disappointing in that less relief than that specified was actually produced during the embossing process. It is also anticipated that this problem can be eliminated in production by using higher embossing pressures, possibly augmented with heat.

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* One of the original program requirements was that the test vehicle should not be altered or damaged by the addition, use, or removal of the camouflage.

FIGURE 11. ARTIFICIAL CAMOUFLAGE LEAF BUNDLES IN THE PACKED CONFIGURATION ON A M151-A2 JEEP

FIGURE 12. ARTIFICIAL CAMOUFLAGE IN THE ERECTED CONFIGURATION ON A M151-A2 JEEP

FIGURE 13. CAMOUFLAGED M151-A2 JEEP PHOTOGRAPHED AT A DISTANCE OF APPROXIMATELY 50 METERS

FIGURE 14. M151-A2 JEEP PHOTOGRAPHED AT A DISTANCE OF APPROXIMATELY 50 METERS

Description of Major Concepts Considered

During the course of this research, a number of concepts were generated as candidates for pop-up or easily deployable artificial foliage. This section presents these concepts and discusses their major advantages and disadvantages.

The first system concept generated consisted essentially of the same spring leaf modules ultimately selected for development combined with a spiral spring tube ("magic cane"). This concept is shown schematically in Figure 15. The spring leaves and tube are stored in the compressed state in a small container or module as shown in Figure 16. The spacer lanyards allow the spring leaf clusters to expand fully. The container lid itself keeps the spring leaves and tube compressed. Release of the lid allows the spring tube and leaves to "pop-up" and expand of their own accord. A variation of this same concept is shown in Figure 17 which also incorporates the fairlead clip idea to aid in folding the spring leaves.

It was discovered that the spring modules alone provided sufficient expansion without the aid of a spring tube. For simplicity, therefore, the spring tube was eliminated.

A second system concept generated was named the "umbrella concept" and is shown in Figure 18. This system consisted of nylon mesh supported by wire ribs and a central spring tube. Thin artificial leaves were to be attached to the nylon mesh. The system would be stored in a module as shown in Figure 19. Attachment to the vehicle and activation would be similar to the preceding concept. The major advantage anticipated for this system was the ability to repack the "foliage" in a relatively short period of time. This system is also relatively simple, durable and capable of instant deployment.

A working model of this concept was constructed as shown in the stowed position in Figure 20 and in the expanded position in Figure 21. The container used for this model is simply a square plywood box. The "branches" were made from 0.015-inch spring steel and are 1-inch wide and 36-inches long. Stiffness of the branches is obtained by deforming the cross section similiar to the configuration used in a steel measuring tape. The branches are forced to "pop-up" by a small coil spring when a retaining pin is removed,

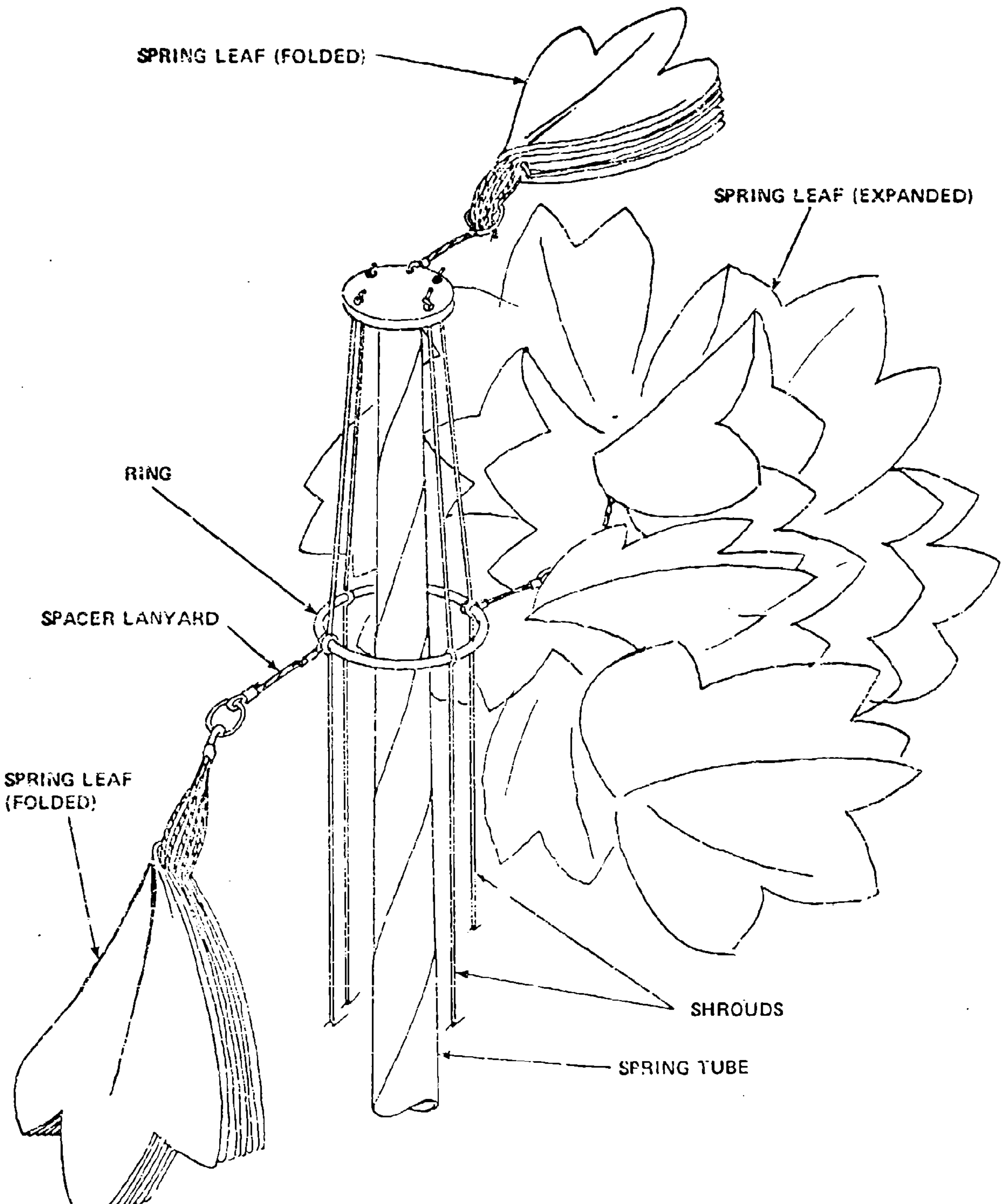

FIGURE 15. SCHEMATIC OF SPRING TUBE-SPRING LEAF CAMOUFLAGE CONCEPT

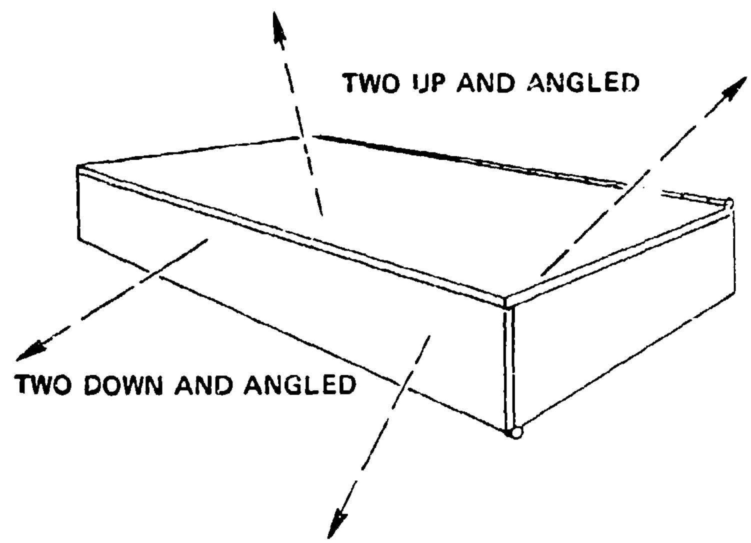

FIGURE 16. ARTIFICIAL CAMOUFLAGE MODULE IN PACKED CONFIGURATION SHOWINC ORIENTATION OF COMPRESSED SPRING TUBES

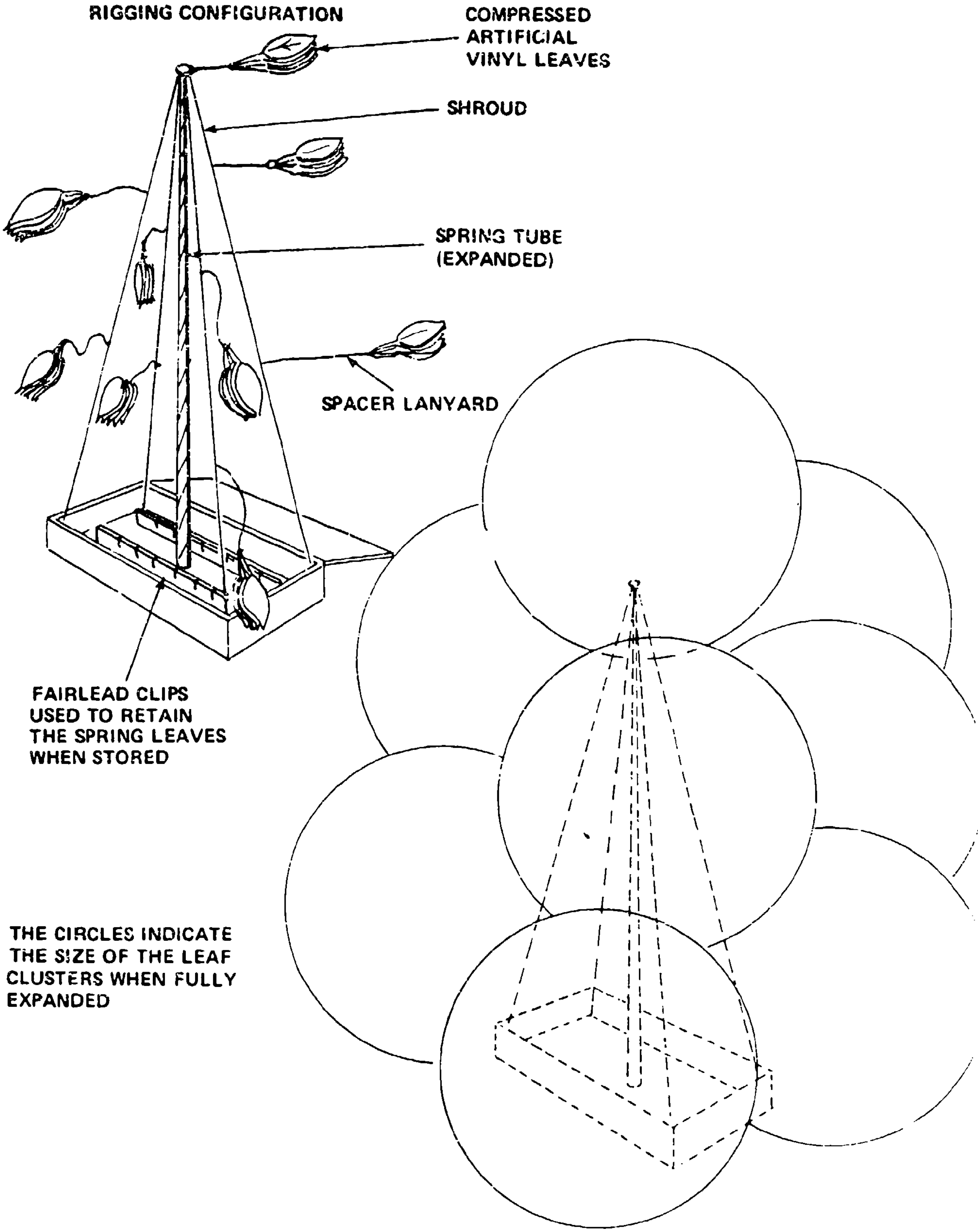

FIGURE 17. VARIATION OF SPRING TUBE - SPRING LEAF CONCEPT WITH FAIRLEAD CLIPS

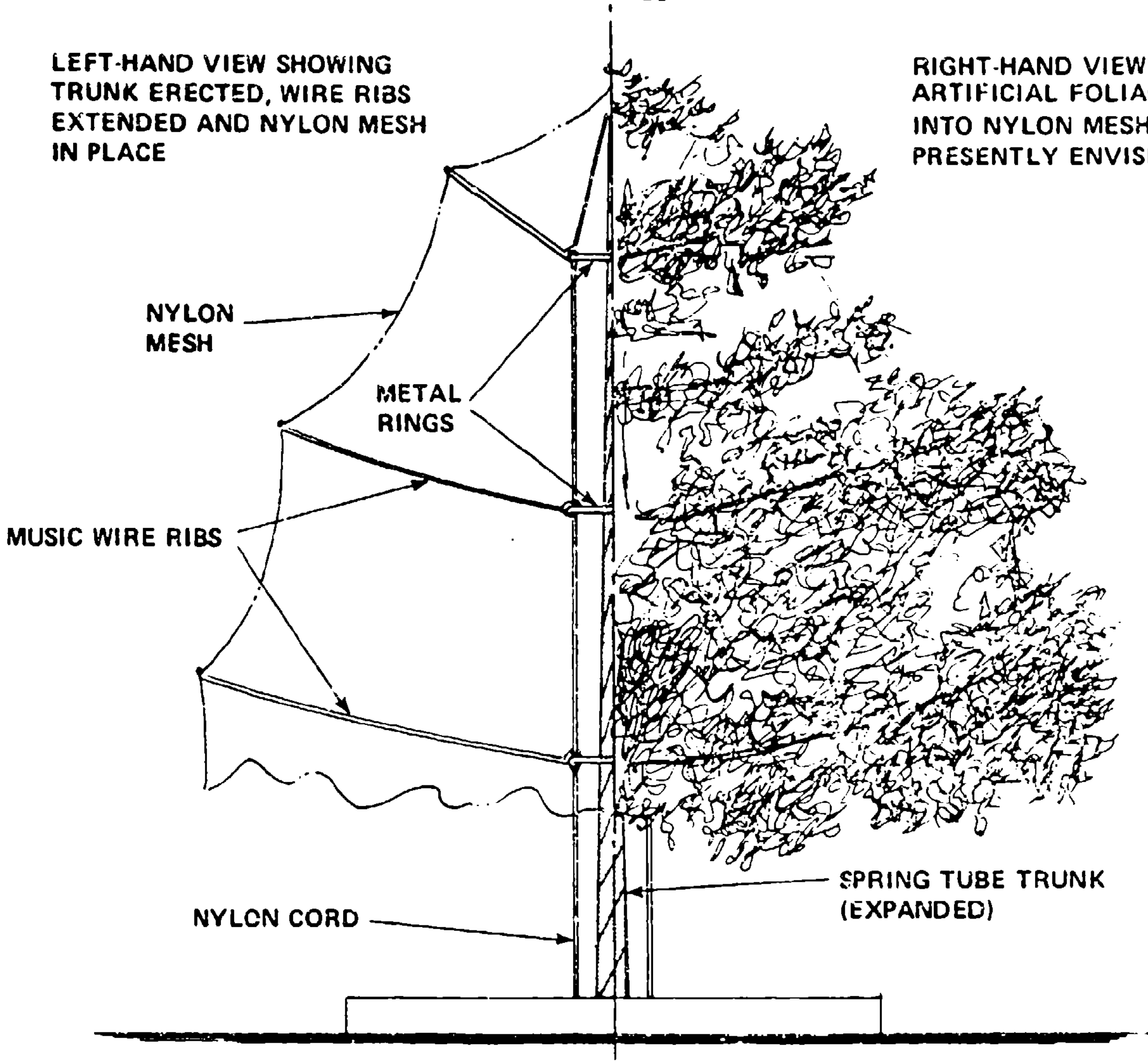

FIGURE 18. "UMBRELLA CONCEPT" FOR POP-UP ARTIFICIAL CAMOUFLAGE

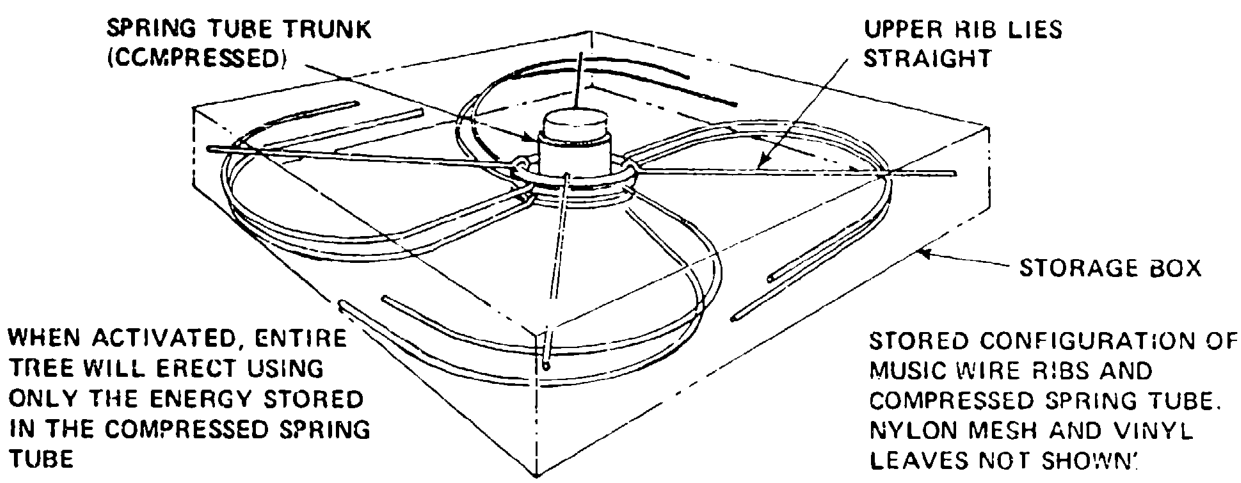

FIGURE 19. "UMBRELLA CONCEPT" IN STOWED POSITION

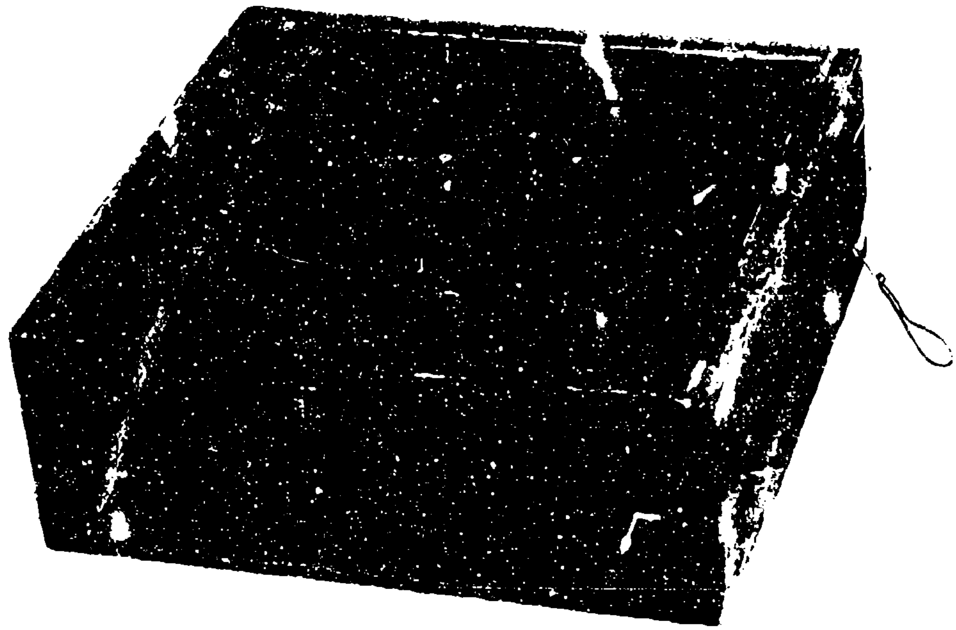

FIGURE 20. "UMBRELLA CONCEPT" MOCKUP IN STOWED POSITION

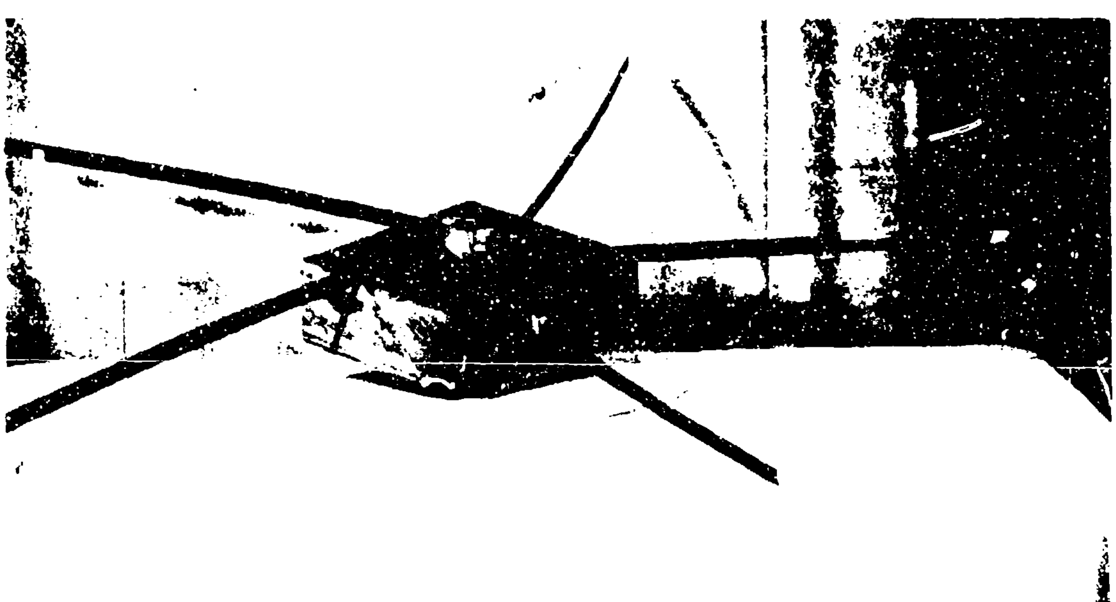

FIGURE 21. "UMBRELLA CONCEPT" MOCKUP IN EXPANDED POSITION

and expand to a 6-foot diameter by their stored spring energy. Although this working model illustrated basic concept feasibility, its potential appeared to be considerably less effective overall than the "magic bouquet" concept.

A third basic approach considered was named the "Christmas Bell" concept. The approach was investigated by first determining the glue pattern used in a number of multilayered expandable paper novelties. It was concluded that the simple fabrication technique used could be adapted to almost any material, provided that it could be joined to itself (e.g., by gluing). Although a large expanded-volume-to-storage-volume ratio can be attained by this technique, the storage container itself would occupy a large surface area; this is due to the two-dimensional expansion characteristics exhibited by this technique as shown in Figure 22.

Development of the "Magic Bouquet" Concept

Analysis of the three major concepts generated indicated that the spring leaf ("magic bouquet") concept appeared to offer the greatest potential for further development. Its major advantages included (1) simplicity, (2) large expanded-to-stored-volume ratio, (3) relatively small surface area required for the storage container, (4) expands in three dimensions, and (5) overall convincing appearance of the expanded disrupter.

A number of descrete areas of investigation were performed during the overall development effort of the spring leaf concept. These included materials investigation, spring design, container design, color selection, methods of activation and repacking, and manufacturability.

As an aid to identify specific problem areas requiring research effort, a first generation mock-up of the device was constructed, approximately one-half projected full size. The spring modules were fabricated from light green paper and ordinary blue spring steel. A simple square steel container with aluminum lid, 8" x 8" x 1-3/4", was also constructed as shown in Figures 23, 24, and 25. Release of the container latch resulted in the cluster shown in Figure 26.

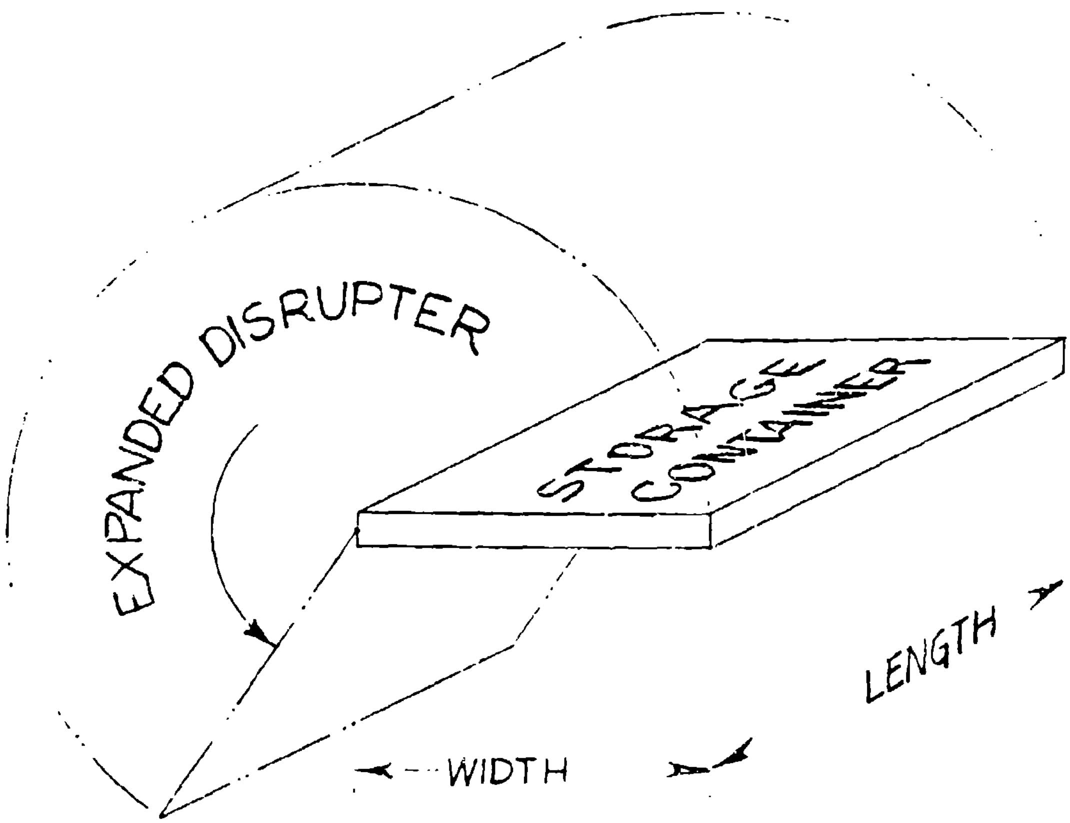

FIGURE 22. "CHRISTMAS BELL" CONCEPT ILLUSTRATING RELATIONSHIP BETWEEN STORAGE CONTAINER AND EXPANDED DISRUPTER

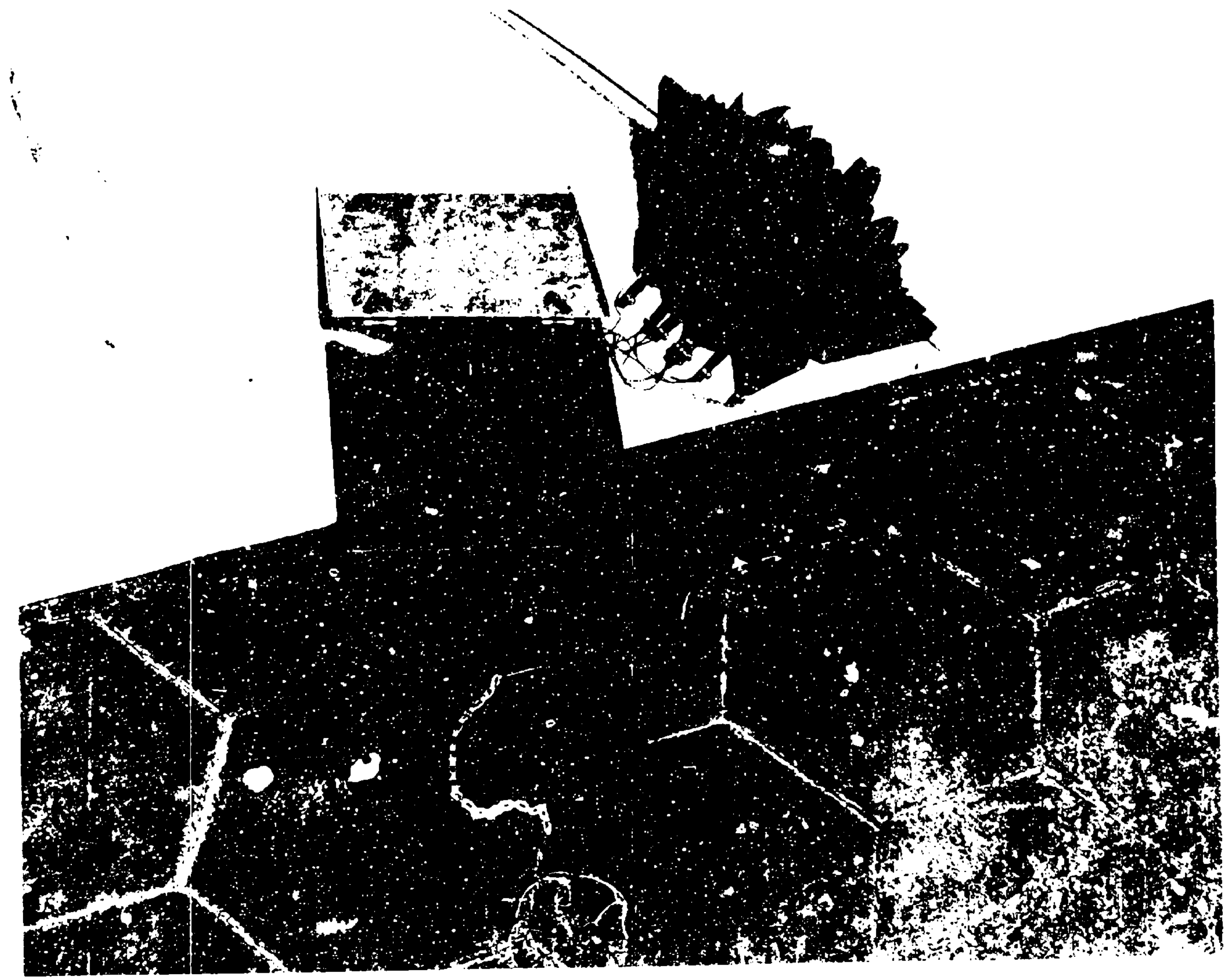

FIGURE 23. CONTAINER FOR THE "MAGIC BOUQUET" CONCEPT

FIGURE 24. "MAGIC BOUQUET" CONCEPT-PACKING THE FIRST EIGHT LEAF MODULES IN THE CONTAINER

FIGURE 25. "MAGIC BOU LEAF MODULES PACKED INTO CONTAINER

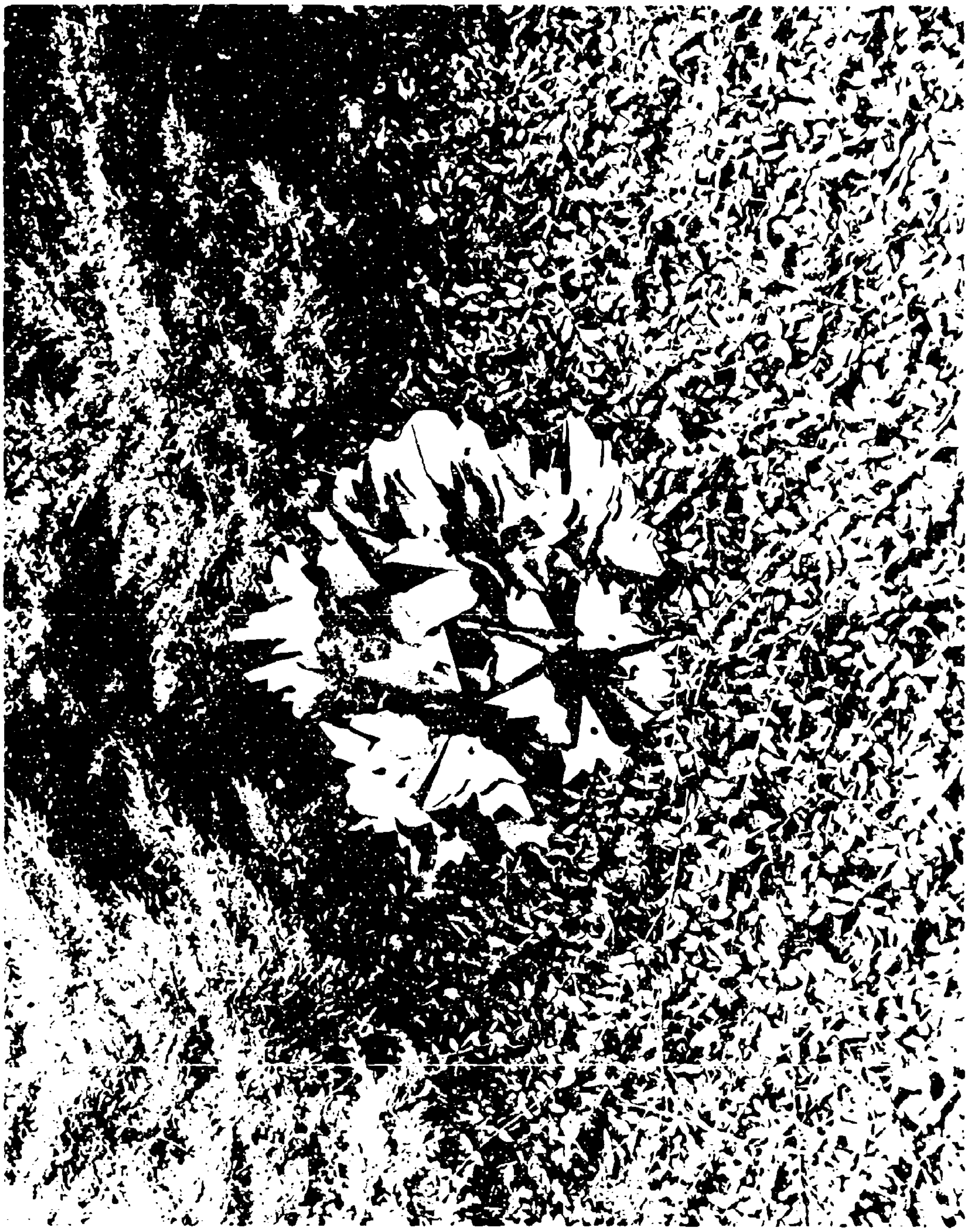

FIGURE 26. "MAGIC BOUQUET" CONCEPT-EXPANDED

The favorable operation of this first generation model inspired the design of full size second generation leaf modules. Emphasis of the second generation module design was to increase the realistic appearance of the "leaves" through better color match with the environment and die-cutting of a more realistic leaf pattern. Spring stiffness was increased proportionately. Sixty-five pound cover weight light green paper was selected for the leaf material and a leaf pattern obtained from a photograph of actual leaves was printed on the paper using PMS-348 ink. Although only a single color print process was used, the overall effect was considered reasonably good. The printing, scoring, folding, die cutting, and gluing of the leaf material was performed by a local printing company and the springs were manufactured by a local job shop spring company. The resulting module, shown in Figure 27, was a significant improvement over the first generation modules.

On September 8, 1973, visual background experiments were conducted at our 1,100 acre outdoor test facility at West Jefferson, Ohio. The modules were placed on the vehicle manually and the vehicle was subsequently driven to four different background locations where numerous photographs were taken.

Figure 28 shows the M38A1 jeep and the leaf modules used in the experiment. The modules were temporarily stored in the folded mode on rods made for this purpose. Two hundred and sixteen (216) modules are shown in Figure 28, and the total weight of the leaf modules was approximately 50.5 pounds.

Figure 29 shows the modules being attached to the vehicle. Careful scrutiny of the photograph will show the printed leaf pattern on the leaf modules. Figure 30 is a photograph of the vehicle taken at a distance of approximately 150 feet.

Figure 31 is a front view of the vehicle indicating the partial coverage of the camouflage modules. Figure 32 is a side view of the vehicle in the same position as Figure 31, taken at a distance of approximately 100 feet. Figure 33 is a telephoto photograph of the vehicle taken at the same distance.

FIGURE 27. SECOND GENERATION LEAF MODULE

FIGURE 28. 216 SPRING-LEAF MODULES, FOLDED AND STORED ON RODS, AND M38A1 JEEP AT WEST JEFFERSON, OHIO, SEPTEMBER 8, 1973 (35 MM FILM)

FIGURE 29. ATTACHING SPRING-LEAF MODULES TO M38A1 JEEP AT WEST JEFFERSON, OHIO (35 MM FILM)

FIGURE 30. M38A1 JEEP WITH SPRING-LEAF CAMOUFLAGE IN PLACE-LOCATED ON CUT GRASS NEXT TO DENSE TREE LINE. (PHOTOGRAPHED AT AN APPROXIMATE DISTANCE OF 150 FEET) (35 MM FILM)

FIGURE 31. FRONT VIEW OF M38A1 JEEP SHOWING PARTIAL COVERAGE OF CAMOUFLAGE ON VEHICLE. (35 MM FILM)

FIGURE 32. SIDE VIEW OF CAMOUFLAGED M38A1 JEEP IN AREA OF LOW GRASS AND HIGH TREES (PHOTOGRAPHED AT A DISTANCE OF 100 FEET) (120 MM FILM)

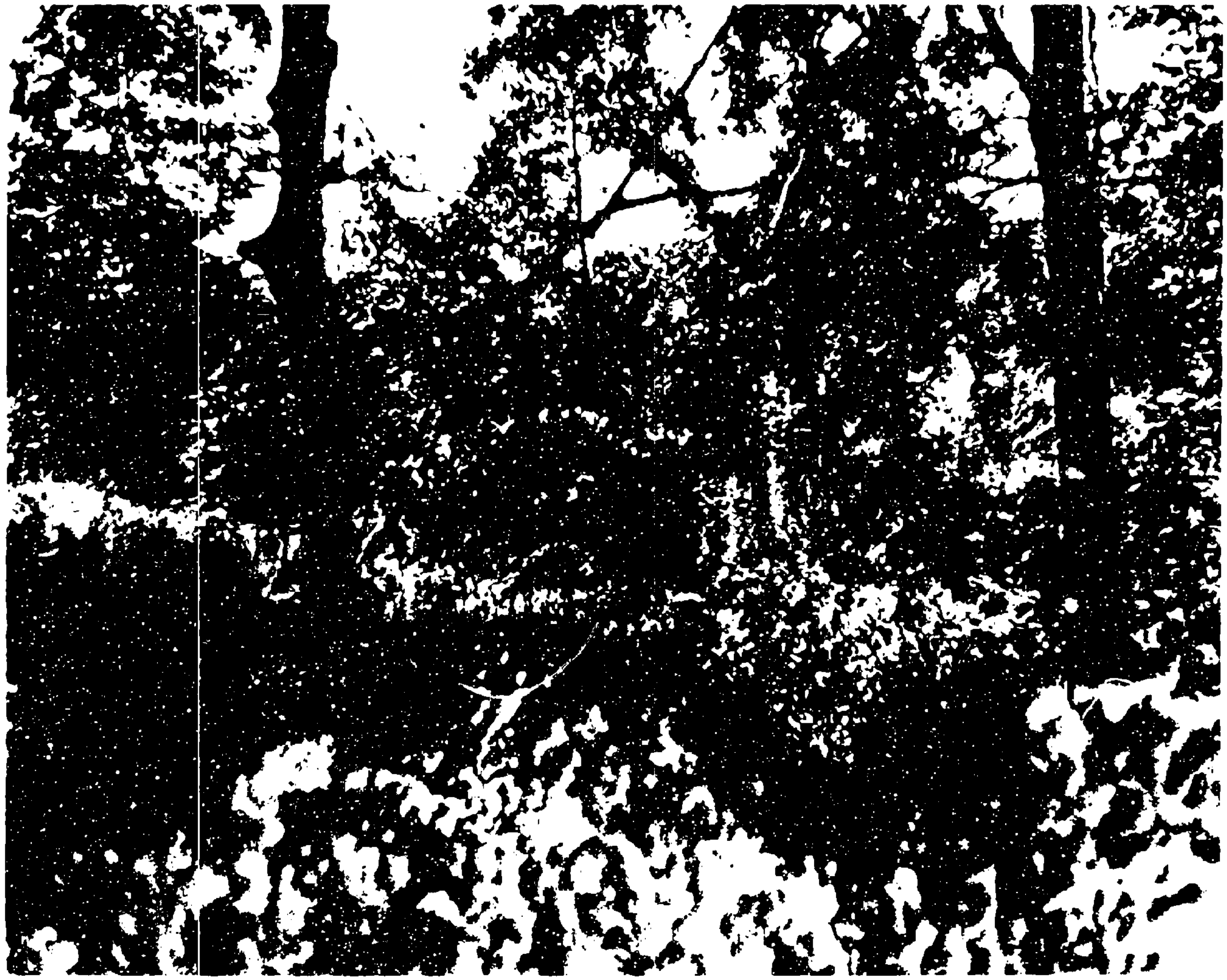

FIGURE 33. SIDE VIEW OF CAMOUFLAGED M38A1 JEEP IN AREA OF LOW GRASS AND HIGH TREES (TELEPHOTO PHOTOGRAPH AT A DISTANCE OF 100 FEET) (35 MM FILM)

Figure 34 is a view of the camouflaged vehicle near a tree line, taken from a distance of approximately 1500 feet and an approximate elevation of 50 feet. Figure 35 is a telephoto shot of the vehicle in the same position.

Figure 36 is a photograph of the vehicle maneuvering in an open field. Figure 37 is a side view of the vehicle in the same field.

As a result of the visual demonstration of the camouflage against the different backgrounds discussed above, it was concluded that the basic spring leaf concept could provide an effective means to hide a vehicle, assuming that surrounding natural foliage was in evidence. Careful scrutiny of the photographs indicated that the artificial foliage modules should be textured or embossed to further break-up light reflectivity, more closely duplicating that occurring in natural foliage by individual leaves.

It required four men approximately one-half hour to "restring" the leaf modules on the rods for ease of transport following the demonstration. This job was judged more time consuming than if actual containers for the modules had been used. It was estimated, however, that two men could repack approximately 450 modules in approximately one-half hour, assuming actual containers or boxes were used for module storage.

Field experiments were conducted at Aberdeen Proving Ground on October 10-11, 1973, to investigate the use of the artificial foliage on a M60 tank and to conduct night vision experiments with the paper camouflage material. Camouflage modules were placed on the turret of a M60 tank in combination with the General Electric aluminized Mylar$^{(R)}$ reflective screen for the lower hull, as shown in Figure 38. Some modules were also used at the junction of the two screens used.

The colors originally selected for the camouflage modules were based on the background colors of mid-summer. The autumn colors at Aberdeen were therefore considerably different; as a silhouette disrupter, however, the concept was judged effective. Night vision experiments using light amplification devices indicated that the artificial foliage looked somewhat darker than the surroundings. Natural foliage appeared to have a greater percentage of leaves oriented such that numerous "bright spots" were visible, thus giving the overall appearance of brightness. The artifical foliage had "spots" equally as bright but these spots were fewer and somewhat larger.

FIGURE 34. CAMOUFLAGED M38A1 JEEP NEAR TREE LINE WITH FIELD OF HIGH GRASS IN FOREGROUND (PHOTOGRAPHED AT A DISTANCE OF 1500 FEET) (120 MM FILM)

FIGURE 35. CAMOUFLAGED M38A1 JEEP NEAR TREE LINE WITH FIELD OF HIGH GRASS IN FOREGROUND (TELEPHOTO PHOTOGRAPH AT A DISTANCE OF 1500 FEET) (35 MM FILM)

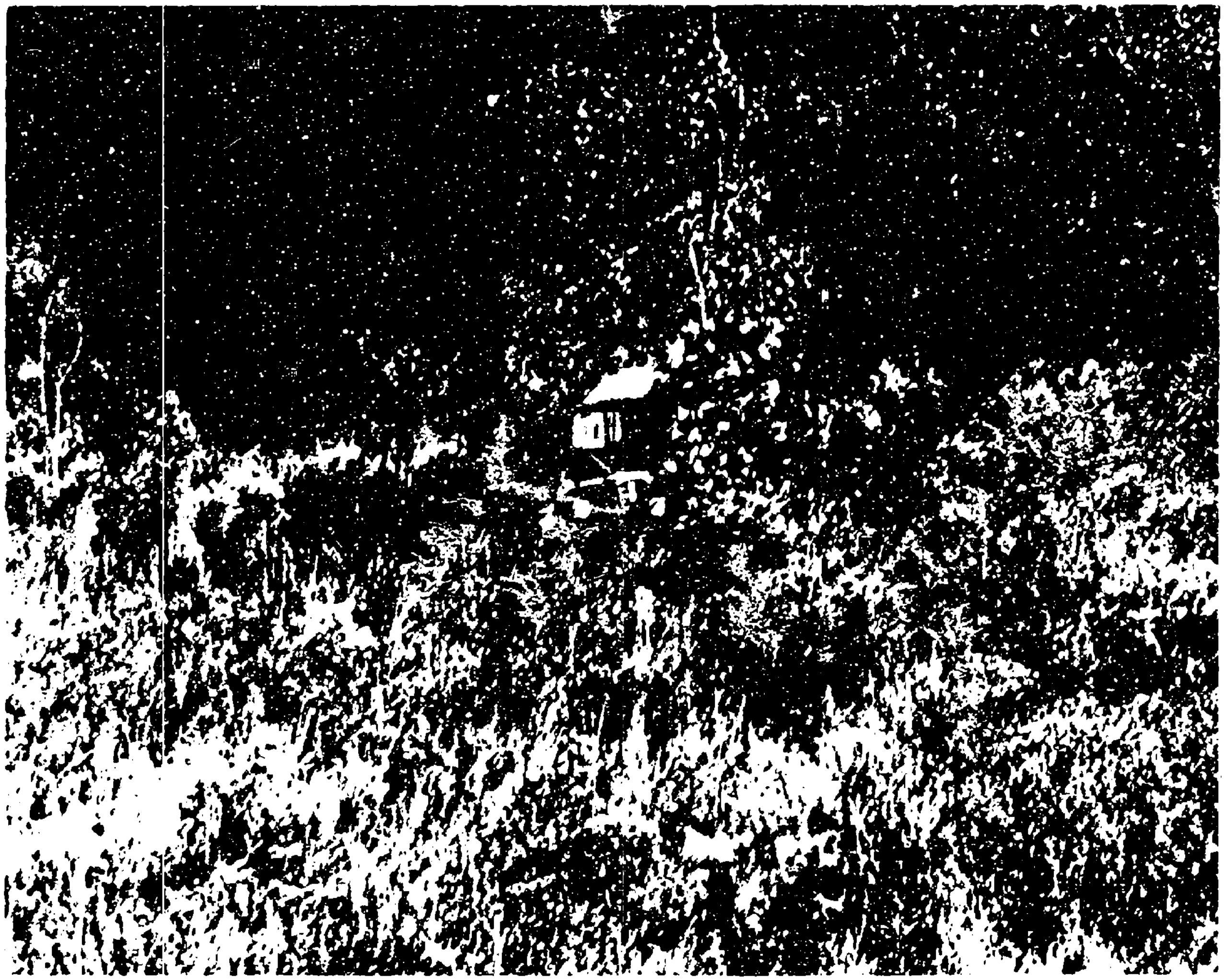

FIGURE 36. PARTIALLY CAMOUFLAGED M38A1 JEEP MANEUVERING IN OPEN FIELD OF LOW GRASS (35 MM FILM)

FIGURE 37. CAMOUFLAGED M38A1 JEEP IN OPEN FIELD
(TELEPHOTO PHOTOGRAPHED) (35 MM FILM)

FIGURE 35. CAMOUFLAGE MODULES IN PLACE ON TURRET OF M-60 TANK AT ABERDEEN PROVING GROUND

As a result of these field experiments, a number of design modifications were formulated. These included further increasing the life-like appearance of the modules, increasing spring strength without increase of module weight, decreasing module density while simplifying fabrication, increasing overall module size, increasing material strength, and providing an effective re-packing technique.

Embossing a leaf pattern on the leaf modules was suggested to more closely duplicate the reflectivity of natural foliage. Interior die cutting with or without embossing was also considered. Various spring designs were formulated to increase spring force without significantly increasing overall leaf module weight or storage volume. One spring concept utilized a corrugated (in cross section) design. A mock-up of this idea indicated that it was expensive to manufacture and it did not function as well as a simple rectangular (in cross section) leaf spring. Mathematical and experimental analysis of springs of various rectangular cross sectional areas indicated that doubling the leaf spring thickness would effectively increase the resultant spring force by eight times for the same spring width. Concurrently, doubling the spring thickness and halving the spring width would result in four times the spring force with the same net weight. This approach was selected as a relatively simple solution to the problem of increasing net spring force.

Each second generation leaf module consisted of two paper sub-modules glued together. The leaf material required was effectively halved by eliminating one of the sub modules. This is shown in Figure 39.

The large number of modules estimated per vehicle indicated that the module size should be increased, thus decreasing the number of descrete modules required to cover a given surface area. A fifty-percent increase in module size (by linear measurement) was selected.

An extensive materials investigation was conducted to increase overall weatherability and material strength above that for the ordinary paper used for the second generation modules. This investigation included consideration of (1) the feasibility of waterproofing the present material, (2) other papers, and (3) other materials such as plastics and commercially-available products whose physical properties appeared attractive to this

FIGURE 39. COMPARISON OF ORIGINAL SECOND GENERATION LEAF MODULE (LEFT) WITH SIMPLIFIED VERSION (RIGHT)

application. Each of these efforts were pursued as follows:

<u>Studies to Examine the Feasibility of Waterproofing the Present Material</u>. The present printed papers stock used to demonstrate a spring-loaded leaf array was selected for waterproofing studies. These studies were designed only to examine the feasibility of waterproofing.

Samples, approximately 3/4 x 4-inches in size, were cut from the leaf-printed paper, placed in a constant temperature-humidity atmosphere of 76 F 50% R.H., and weighed. A waterproofing agent ("Silicone", Chem-Sol) was selected because of (1) its known composition of pure silicone without adulturants; and (2) its ease of application from an aerosol can. Both high humidity and immersion studies were conducted and the results are documented in Table 1.

One group of samples (Nos. 9-12 and 13-16, Table 1) was given a light coat of silicone and another group of samples (Nos. 17-20 and 21-24, Table 1) was given a heavy coat. A third group (Nos. 1-4 and 5-8, Table 1) was not coated and was used as a control. All samples were force dried for 3 hours at 120 F and allowed to return to constant temperature-humidity before reweighing to determine the amount of silicone pickup.

To obtain maximum exposure to high humidity, half of each sample group was placed in a dessicator containing water. The remaining samples were completely immersed in water. After 16 hours of exposure all samples were reweighed to determine water pickup.

Stiffness measurements were made on the plain paper, the water-proofed samples, and the "wet" samples after exposure. TAPPI test method T 489 M-60 was used to obtain a comparative value of stiffness of the samples. Measurements were made on the Taber Stiffness Gauge which comparatively quantifies stiffness in units.

Data obtained from this study can be summarized in Tables 2 and 3.

TABLE 1. WATERPROOFING[1] OF CAMOUFLAGE PAPER[2]

BCL Sample No.[3]	Initial Weight (Grs)	Wt. After Coating (Grs)	Silicone Pickup (Grs)	Stiffness[4] Before Exposure Units	Stiffness[4] Before Exposure Avg.	Wt. After Exposure (Grs)	H_2O Pickup Weight	H_2O Pickup Percent	H_2O Pickup Avg.	Stiffness[4] After Exposure Units	Stiffness[4] After Exposure Avg.	Stiffness Change (Loss) After Exposure Units	Stiffness Change (Loss) After Exposure Percent
HIGH HUMIDITY EXPOSURES[5]													
1	.3854	--	--	15		.5976	.2122	55		16		2	
2	.3749	--	--	15	16	.5849	.2080	55	53	17	15.7	2	15
3	.3892	--	--	17		.5891	.1999	51		14		3	
4	.3895	--	--	18		.5735	.1980	52		16		2	
9	.3796	.4397	.0601	17		.6118	.1721	39		15		2	
10	.3876	.4284	.0408	16	16	.6287	.1803	42	40	15	14.5	1	9
11	.3657	.4138	.0481	15		.5887	.1749	42		14		1	
12	.3792	.4184	.0392	16		.6440	.1648	39		14		2	
17	.3714	.5487	.1773	17		.6938	.1451	26		17		--	
18	.4088	.5819	.1731	16	17	.7352	.1533	26	26	17	16.5	1	3
19	.4019	.5625	.1606	17		.7118	.1493	26		16		1	
20	.3683	.5012	.1329	16		.6394	.1382	27		16		--	
H_2O IMMERSION EXPOSURES[6]													
5	.3833	--	--	17		.6034	.2201	57		14		3	
6	.3746	--	--	18	17.2	.5754	.2008	53	55	16	14.7	2	15
7	.3876	--	--	18		.6089	.2213	57		15		3	
8	.3749	--	--	16		.5762	.2013	53		16		2	
13	.4013	.4540	.0527	14		.6453	.1913	42		12		2	
14	.3876	.4229	.0353	15		.6025	.1796	42		16		1	
15	.3924	.4698	.0774	12	13.7	.6520	.1822	39	40	10	12.7	2	11
16	.3880	.4479	.0599	14		.6279	.1800	40		13		1	
21	.4032	.5722	.1690	15		.7323	.1601	28		14		1	
22	.3894	.5445	.1551	14	14.7	.6944	.1499	27	27	12	13	2	11
23	.4017	.5725	.1708	14		.7314	.1589	27		12		2	
24	.3924	.5642	.1718	16		.7165	.1523	27		14		2	

(1) Waterproofing agent is "Silicone" (Chem-Sol).

(2) Stock leaf-printed paper as used in spring-opening display.

(3) Original data are in Battelle Laboratory Record Notebook No. 30797.

(4) Stiffness measured on Tabler-Stiffness Gauge. Values are "stiffness units" as outlined in TAPPI test method T 489 m-60. Each value is the average of two readings.

(5) Samples placed in high humidity atmosphere (wet desiccator) for 16 hours.

(6) Samples immersed in H_2O for 16 hours.

TABLE 2. HIGH HUMIDITY EXPOSURE STUDY

Group	Water Pickup (percent)	Loss in Stiffness (%)
control (no coating)	53	15
light silicone coating	40	9
heavy silicone coating	26	3

TABLE 3. WATER IMMERSION EXPOSURE STUDY

Group	Water Pickup (percent)	Loss in Stiffness (%)
control (no coating)	55	15
light silicone coating	40	11
heavy silicone coating	27	11

From the data in Table 1, it can be concluded that waterproofing is an acceptable method of upgrading the performance of the present camouflage paper. There are undoubtedly other coating or treating materials available that would help to waterproof this paper.

Consideration of Other Papers. Many different paper stocks from parchment to outdoor poster board were considered for this application. Most of these were rejected because of the severe trade-off between thickness and stiffness. Since there were no serious limitations which could not be overcome with the present material, no further efforts were made to examine other papers at this time.

Consideration of Plastics and Commercially-Available Products. Many plastic products such as vinyl, polyethylene, acetates, etc., are excellent candidates for this application. However, because of the uncertainties associated with current market availability of most raw plastics, it was decided to limit the search to commercially-available materials. A local printer who has access to embossing facilities was contacted for assistance. The normal properties of light weight with toughness, minimum thickness with acceptable stiffness, and color receptivity were unchanged. Additional properties of moisture resistance, flame retardancy, and receptiveness to embossing were added.

After several telephone and personal contacts, three products were selected for study, Tensalex (Sorg Paper Company), "Acro Art" (Mead Paper Company), and "Tex-O-Print" (Kimberly Clark). "Acro Art" was ultimately selected because of its high tear strength and ability to retain essentially 100 percent of its strength under full immersion. This product is apparently a totally synthetic paper and currently appears available in adequate quantity.

The major difficiency associated with the second generation spring-leaf concept was repacking. Although not inherently difficult, the repacking process is time consuming. Considerable effort was expended to consider approaches to aid or facilitate a repacking process. These approaches were segregated into three major areas:

(1) Repacking aids and equipment directly applicable to the existing leaf module design.

(2) Redesign of the existing leaf module concept to facilitate repacking.

(3) Throw-away leaf modules with replaceable cartridges (for use only when time is not available for repacking).

The first packing procedure involved manually closing each spring leaf module and manually holding all modules previously closed in the compressed mode until all modules associated with a given container are compressed. Retention of the previously closed modules in the compressed state was identified as one of the major difficulties. Figure 40 illustrates a concept to aid in the retention of the modules in the compressed mode, freeing the repacker

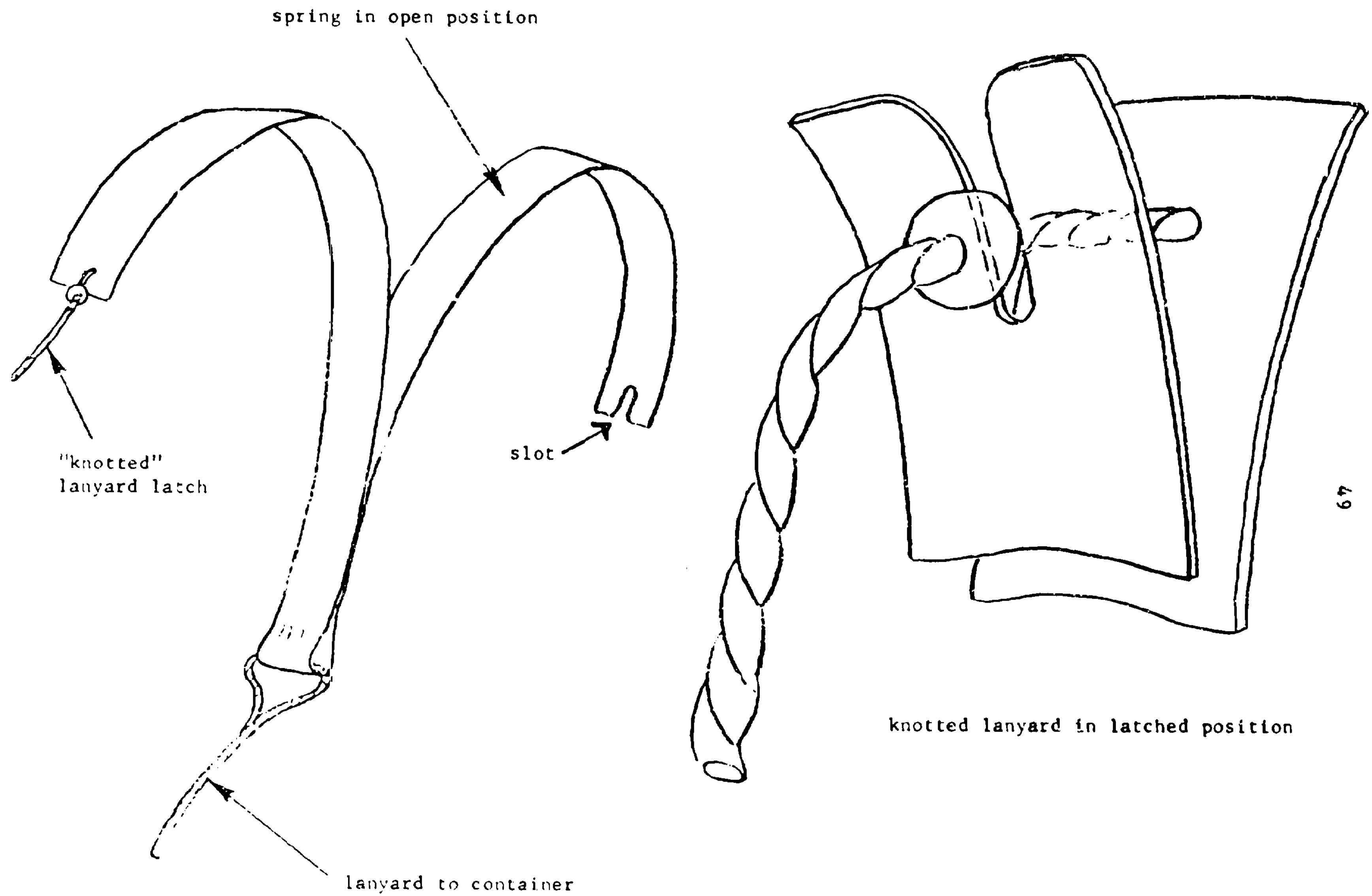

FIGURE 40. LATCH CONCEPT TO FACILITATE RETENTION OF SPRING LEAF MODULES IN THE COMPRESSED MODE.

to concentrate on the actual closing operation. This concept consists of a small latch which holds the leaf module in the closed position. The concept illustrated in Figure 40 is simply a small knotted lanyard or wire which is fastened to one spring and slips into a slot in the mating spring when the module is compressed, thus holding the module closed. It is important to note that the latches must be released following placement of the modules into the storage container.

Other ideas, such as pulling the leaf modules through a fairlead-type arrangement were considered. The random orientation of the leaf modules when deployed was considered to be the major drawback to this approach since some means of orientation had to be accomplished prior to entering the fairlead.

Since module orientation was identified as a major problem, work was initiated to redesign the spring leaf module slightly such that it need no orientation prior to its entry into a fairlead-type repacker. The concept resulting from this effort is shown in Figures 41-43. Figure 41 is a photograph of one spring leaf module (non-operating mockup). It consists of a number of stem-like wire springs, each with a number of relatively soft highly compressible discrete leaves. The fountain-like arrangement of the wires can be pulled into a horn-shaped fairlead by its lanyard as illustrated in Figure 42. Figure 43 is a sketch of the leaf modules in the deployed mode. The overall concept is similar in principle to the current spring leaf design. The major problem anticipated with this idea is deployment, since the relatively thin wires visualized for the "stems" may not contain sufficient stored energy to be self erecting.

A conditional throwaway idea was also considered. The leaf modules would ordinarily be repacked manually using one or more aids to facilitate the process. However, during emergencies, the modules can be discarded and replaced with a "cartridge"-type leaf module container which is either stored on board the vehicle itself or carried in a supply vehicle. Utilization of relatively inexpensive light weight materials and increasing the expanded volume to stored volume ratio (above that already achieved) would strengthen the attractiveness of this idea.

FIGURE 41. PHOTOGRAPH OF MOCK-UP OF WIRE STEM SPRING LEAF MODULE

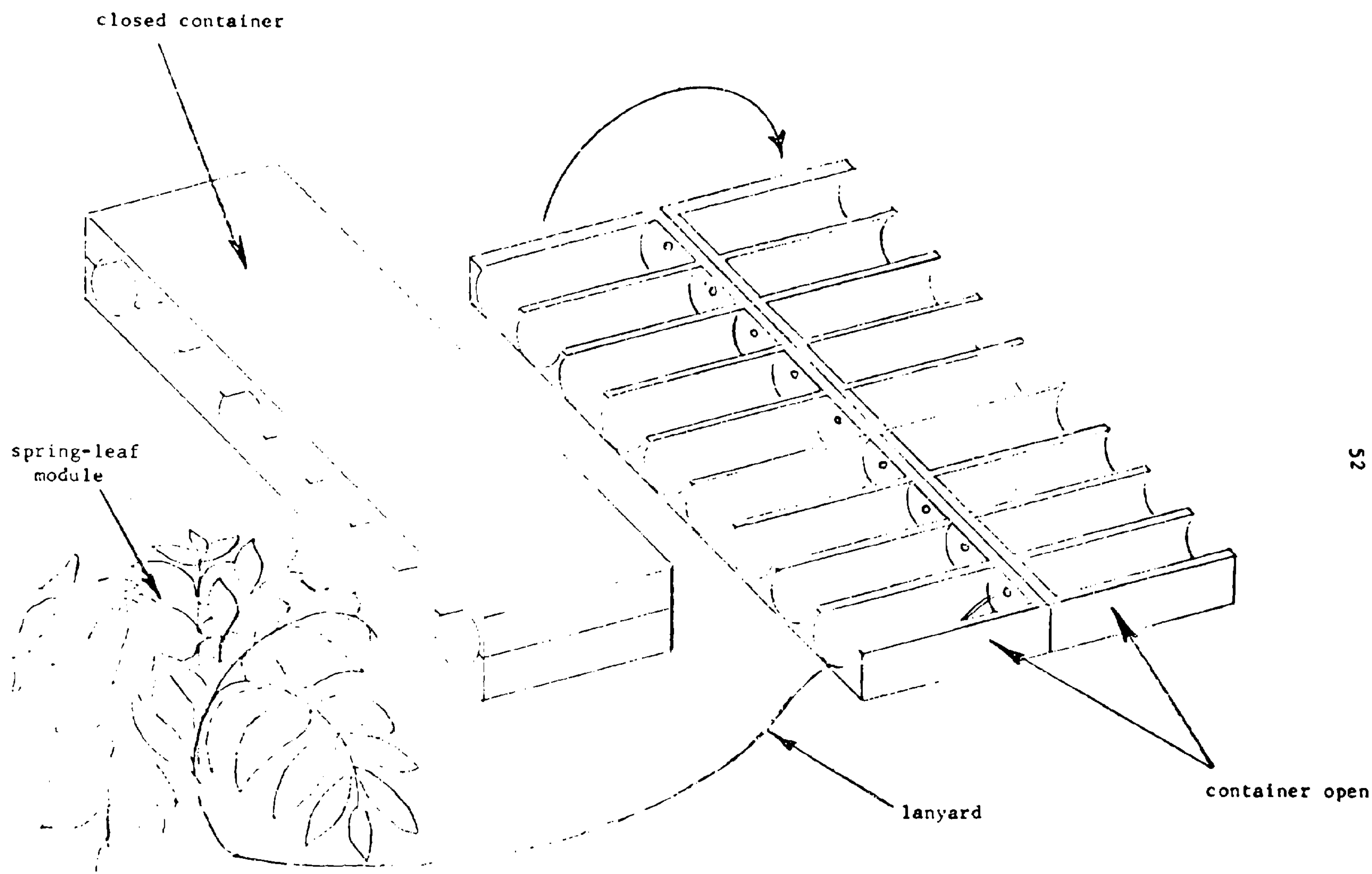

FIGURE 42. SPRING-LEAF MODULE, LANYARD, AND CONTAINER

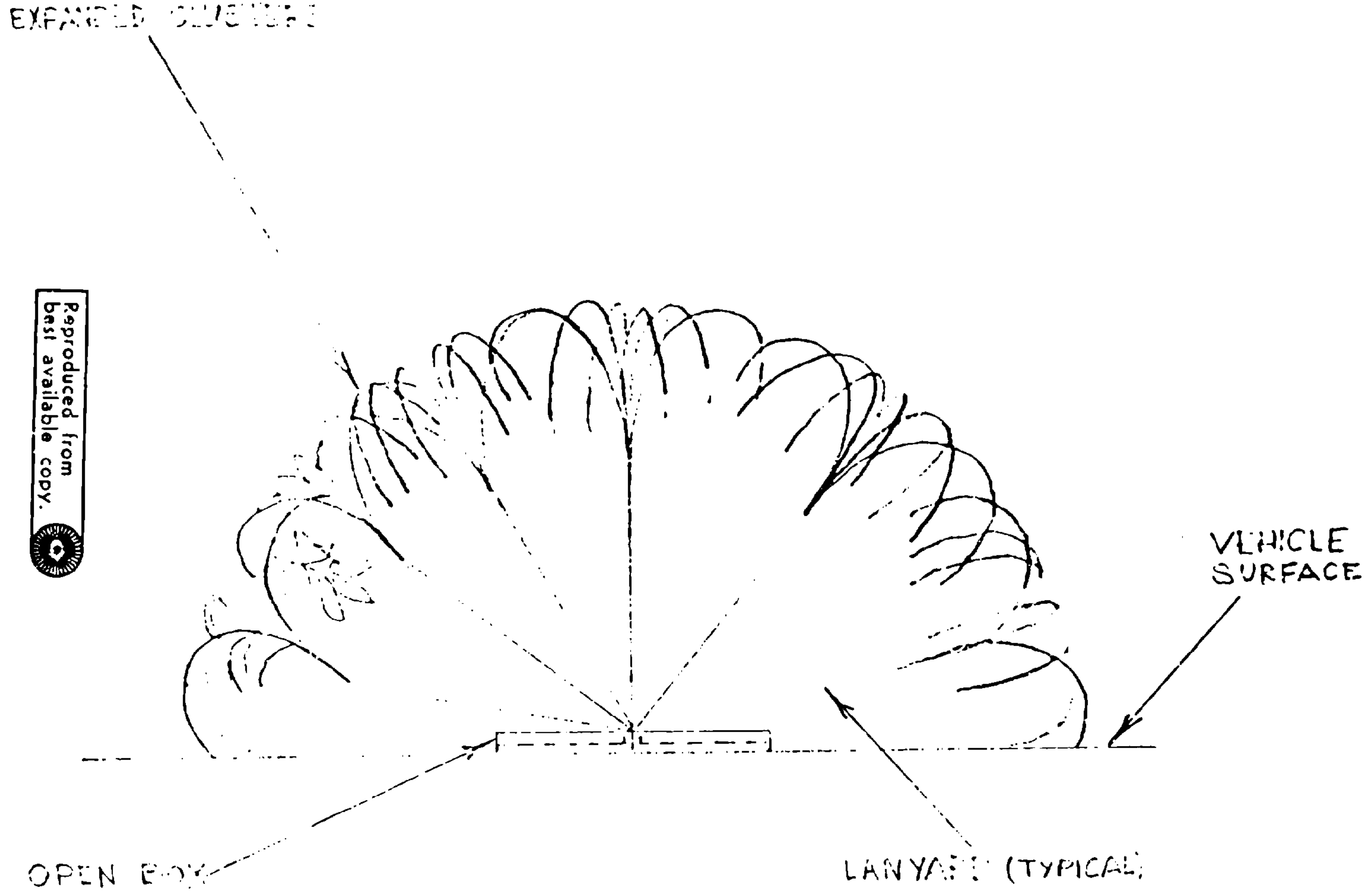

FIGURE 43. SCHEMATIC OF LEAF MODULES IN DEPLOYED MODE.

A solution to this problem was ultimately devised using a lanyard threaded through all leaf modules. This technique was illustrated previously under "Description of Pop-Up Artificial Foliage Concept".